LA-UR-19-26466
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Title:	Characterizing Nuclear Material Out of Regulatory Control: Testing Los Alamos National Laboratory’s Nuclear Forensics Capabilities
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Intended for:	DDSTE Highlights
Issued:	2019-07-09

Characterizing Nuclear Material Out of Regulatory Control: Testing Los Alamos National Laboratory's Nuclear Forensics Capabilities

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In 2019, Los Alamos National Laboratory (LANL) researchers participated in the sixth Collaborative Materials Exercise (CMX-6) organized through the Nuclear Forensics International Technical Working Group (ITWG). The ITWG is a multinational, informal association of official practitioners of nuclear forensics and includes laboratory scientists, law enforcement personnel, and regulatory officials. It is affiliated with nearly 40 countries and international organizations and has the mission of working to combat nuclear terrorism and proliferation.

Based on a realistic scenario, CMX-6 was designed to exercise laboratory capabilities to forensically examine nuclear material found out of regulatory control, and support the ITWG goal to "advance the scientific discipline of nuclear forensics and to provide a common approach and effective technical solutions to competent national or international authorities that request assistance." During this exercise, laboratories around the world each received two radioactive material samples that had been seized from a fictional metal recycling plant, a cerium metal block and a depleted uranium metal block, both contaminated with plutonium fluoride and hidden within multiple layers of plastic bags in rusty pipes (Figure 1). The CMX-6 exercise was the second time in ITWG CMX history in which test samples included a plutonium component which made shipping, handling, and analysis considerably more challenging.

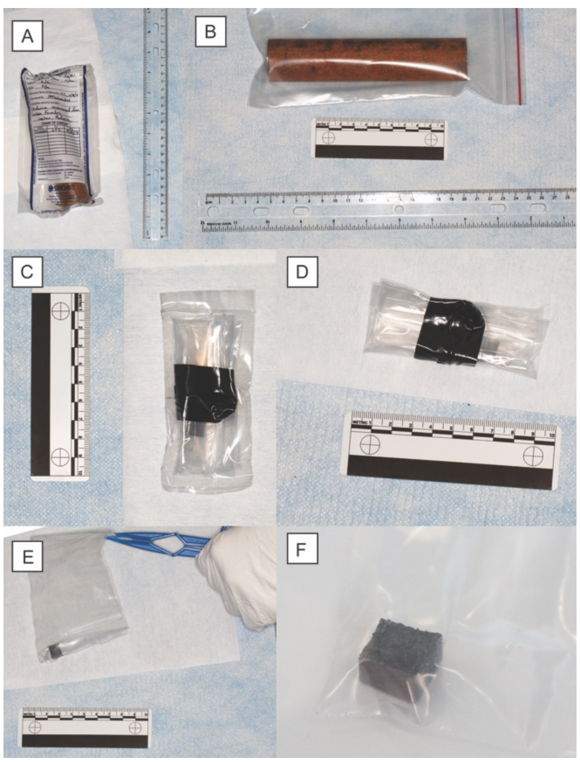

Figure 1. Photographs of sample receipt of a depleted uranium block (F) packaged within a rusty pipe (B).

Los Alamos National Laboratory participants in CMX-6 included 38 staff from four groups (C-NR, C-AAC, C-IIAC, and A-2). Samples received by C-NR at Technical Area 48 from Savannah River National Laboratory were opened on March 6, 2019 for both non-destructive and destructive analysis. Non-destructive analyses conducted at LANL included photography, gamma-ray spectrometry, autoradiography, physical characterization (mass, dimensions, etc.), optical microscopy, elemental mapping by micro-XRF, scanning-electron microscopy, x-ray diffraction, and LIBS. Destructive analyses included secondary ion mass spectrometry, element concentration analysis by ICP-OES and ICP-MS, uranium assay by Davies and Gray titration, mass spectrometry for assay and isotope composition measurements of U, Pu, Th, Am, and Np, and radiochronometry. The exercise required 24-hour, 1-week, and 2-month reporting of data as well as a final assessment of analytical results.

Highlighting Non-Destructive Nuclear Forensics
Optical images and physical characterization for both metal samples were performed inside a radiologically contained open front box in LANL's CMR facility followed by the surface morphology analysis by the SEM and elemental mapping by micro-XRF (Figure 2). These analyses provided important information related to sample processing.

Figure 2. Left – optical image of depleted uranium with colored arrows denoting dimensions measured; Middle – micro-XRF map of composition (blue = uranium, Red = cerium, Green = yttrium); Right – SEM image showing morphology including saw cuts, oxidation, and etch pits.

Highlighting Destructive Nuclear Forensics
The exercise samples were dissolved with acids and elements of interest were purified using radiochemical techniques for mass spectrometry. Plutonium analyses at C-NR confirmed the presence of weapons grade plutonium on both the cerium and depleted uranium blocks. The plutonium contamination was identical in isotopic composition between the two samples. The purities of the uranium and cerium metals, as well as the impurities, were determined by the C-AAC coloumetry and ICP-OES/MS methods. The fact that the uranium metal block contains cerium and yttrium (a major impurity in the cerium metal block) provided a critical nuclear forensic signature, indicating that the two metal blocks are related. Radiochronometry (age dating) was performed at C-NR by measuring the following daughter/parent pairs: $^{230}Th/^{234}U$, $^{241}Am/^{241}Pu$, and $^{237}Np/^{241}Am$. Radiochronometry is an important forensics tool used to help determine the production history of an unknown material. The depleted uranium block had a model $^{230}Th/^{234}U$ production date of April 14, 2018 ± 6 days. The plutonium surface contamination was found to have a considerably older 1965 model production date based on $^{241}Am/^{241}Pu$ (July 13th, 1965 ± 132 days and July 18th, 1965 ± 106 days). Measured $^{237}Np/^{241}Am$ production dates of the plutonium agreed with the $^{241}Am/^{241}Pu$ production ages supporting the conclusion that the plutonium was last purified approximately 53 years before CMX-6.

A data review meeting for CMX-6 was held in Warsaw, Poland in early June of 2019 for all international CMX-6 participants. At the data review meeting, the United States participating laboratories (LANL and LLNL) and the European Commission Joint Research Centre were given an award for excellence in radiochronometry. Participation in CMX-6 and other forensic examinations provides the opportunity to exercise LANL's nuclear forensics capabilities to ensure that LANL scientists are prepared to support nuclear smuggling investigations and other incidents of nuclear or radioactive material found outside of regulatory control.

Report: LA-UR-19-24382 Los Alamos National Laboratory CMX-6 60-Day Report Case ID 369X-HQ-CMX6/2018-CMX6

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